

BELLCOMM, INC.

955 L'ENFANT PLAZA NORTH, S.W.

WASHINGTON, D.C. 20024

B70 11052

SUBJECT: Stars and Planets Visible in the  
LM AOT During the Lunar Stay  
Time of the Apollo 14 Mission  
Case 310

DATE: November 12, 1970

FROM: T. L. Yang

ABSTRACT

The navigation stars and planets which will be visible in the LM Alignment Optical Telescope have been determined for the lunar surface stay period of the forthcoming Apollo 14 mission to Fra Mauro. The locations of the stars and planets and their paths of motion during the surface stay time are shown in the figures. Three monthly windows in 1971 are considered including a total of five landing times - February 5, March 7 and 8 and April 5 and 6.

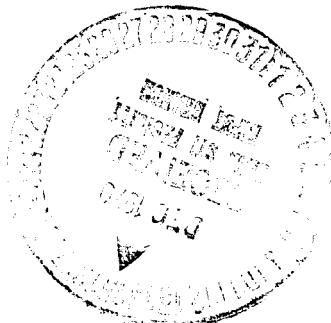
This work is performed in collaboration with the Flight Analysis Branch of the Mission Planning and Analysis Division at MSC for the purpose of verifying the results obtained from two independent sources.

(NASA-CR-111686) STARS AND PLANETS VISIBLE  
IN THE LM AOT DURING THE LUNAR STAY TIME OF  
THE APOLLO 14 MISSION (Bellcomm, Inc.) 10 p

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MEMORANDUM FOR FILE

The navigation stars and planets which will be visible in the LM Alignment Optical Telescope (AOT) have been determined for the lunar surface portion of the forthcoming Apollo 14 mission.\* The line-of-sight to one or more known stars will be used for the alignment of the LM Inertial Measurement Unit while on the lunar surface. The Fra Mauro site is considered for five landing opportunities (see table below) which are associated with the three consecutive monthly launch windows between January 31 and March 31 of 1971.

Alignments will normally be done shortly after landing, and about one half hour before launch. The viewing times of interest, then, are from shortly after landing through the next 30 hours.

DATE OF LUNAR LANDING (1971)		APPROXIMATE FIRST VIEWING TIME (GMT)	SUN ELEVATION ANGLE AT LANDING	ASSOCIATED LAUNCH DATE (1971)
FEB 5		10:00	10.3°	JAN 31 ( $T_O$ )
MAR	7	01:00	10.5°	MAR 1 ( $T-24$ )
	8	01:00	23.0°	MAR 2 ( $T_O$ )
APRIL	5	09:00	8.0°	MAR 3 ( $T+24$ )
	6	13:00	22.0°	MAR 30 ( $T-24$ )
				MAR 31 ( $T_O$ )
				APR 1 ( $T+24$ )

\*Similar work was done for the previous landing missions, see Bellcomm Memoranda for File B69 06099, June 27, 1969, B69 09093, September 29, 1969, and B70 03079, March 26, 1970.

The AOT has a field of view of 60 degrees and can be rotated to any of six distinct positions by the use of detents. The forward detent center line is in the plane containing the spacecraft +x and +z axes. The five remaining detent center lines are located at intervals of 60 degrees measured in the plane containing the spacecraft z and y axes.

The sun, the earth, Venus, Mars, Jupiter, Saturn, and 65 navigational stars are considered in this study. These stars are listed in Table 1. The first 37 stars in the table are listed in the Apollo star catalog; numbers 38 to 65 are other common navigational stars. The visible bodies for each landing opportunity are plotted in the attached figures as they appear in the detents to the observer. In these figures, the inner circles represent the actual AOT field of view (60 degrees), and the outer circles (shown in broken arcs) cover fields of 90 degrees. The extra area outside the 60 degree field of view is provided to cover the situation where the LM does not land with the nominal attitude (level with the +z body axis in the direction of the nominal approach azimuth). The inner circle should be adjusted to account for any difference in landing attitude. A scheme to adjust the fields of view for any given attitude errors has been worked out by K. M. Carlson of Bellcomm (see "AOT Star Chart Compensation for LM Landing Attitude Deviations", Bellcomm Memorandum for File B70 03041, March 13, 1970).

In these figures, the separation angle between a star and the center of the field of view is plotted as linearly proportional to the radial distance from the center. Such a scale is a slight distortion of the actual view but has the advantage of keeping the distortion small if the field is to be shifted.

Except for the forward detent, the optical design of the AOT causes the apparent star field to appear rotated in the eyepiece with respect to what one would see if he simply looked in the direction of the center of the field. The angle of rotation is equal to the angular separation of the detent position from the spacecraft's +z axis measured in the spacecraft y-z plane. For example, the star field in detent 3 (right front), the center line of which is at an azimuth of 60 degrees clockwise from the forward or +z axis, appears rotated 60 degrees clockwise from the true star field. The radial line with an arrow in each inner circle indicates the direction of the local zenith; this line does not exist in the AOT. The reticles are shown as they appear and do not rotate with the star field. The stars are labeled according to the numbers given in Table 1. The positions of the stars at the approximate time of the first viewing are shown in the figures. The line attached to each star, or planet, indicates its path of motion during the 30 hours after the first viewing.

The azimuth of the center line of the forward detent (equal to the assumed landing azimuth) is indicated on each figure. The shaded area appearing in each detent is the rendezvous radar guard obstruction.

*Ta-Lun Yang*  
T. L. Yang

2014-TLY-vh

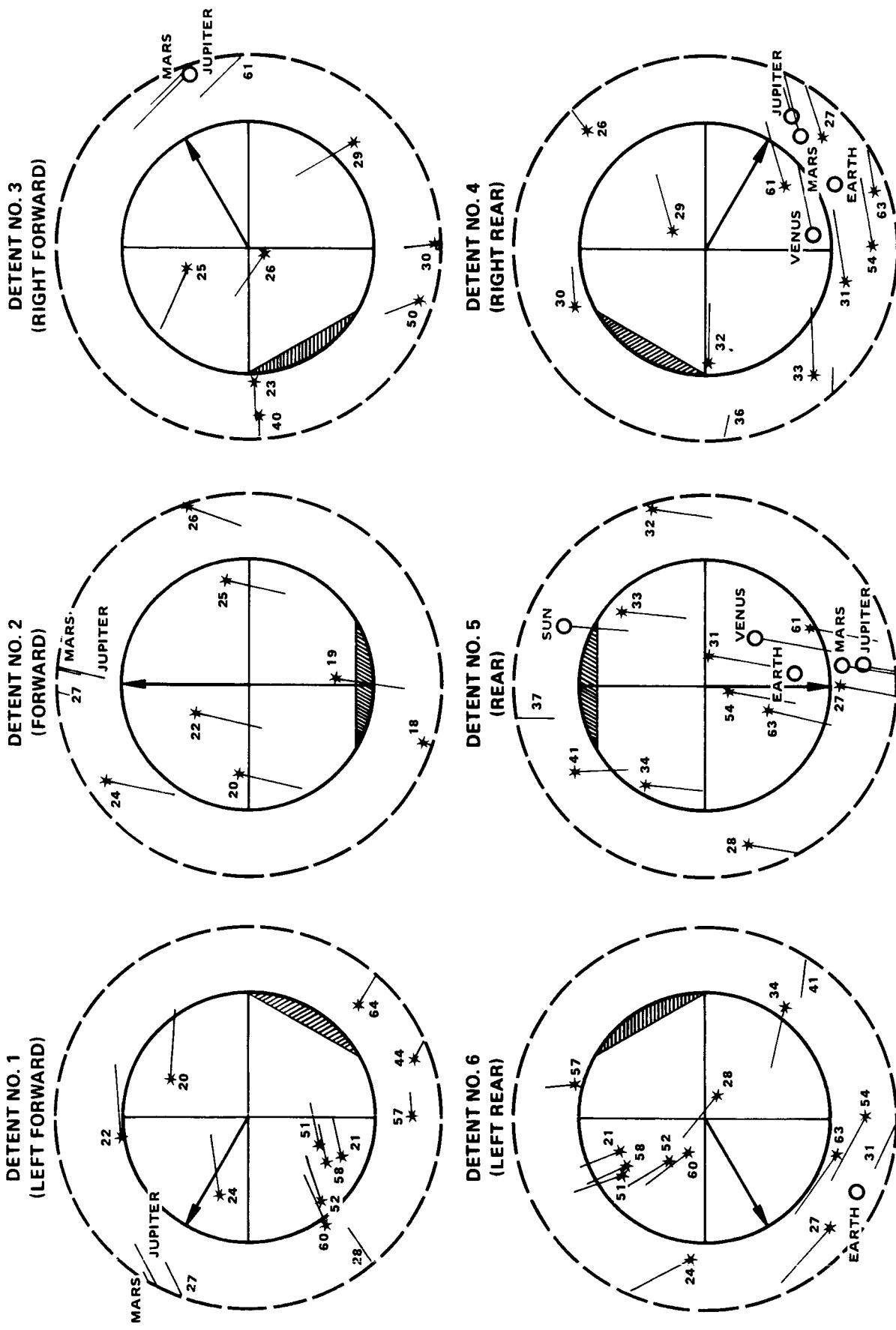
Attachments

Table 1

Figures 1-5

STAR NO.	NAME	STAR NO.	NAME
1	ALPHERATZ ( $\alpha$ ANDROMEDAE)	38	ADHARA ( $\epsilon$ CANIS MAJORIS)
2	DIPHDA ( $\beta$ CETI)	39	ALHENA ( $\gamma$ GEMINORUM)
3	NAVI ( $\gamma$ CASSIOPEIAE)	40	ALIOTH ( $\epsilon$ URSAE MAJORIS)
4	ACHERNAR ( $\alpha$ ERIDANI)		
5	POLARIS ( $\alpha$ URSAE MINORIS)		
6	ACAMAR ( $\theta$ ERIDANI)	41	AL NA ' IR ( $\alpha$ GRUIS)
7	MENKAR ( $\alpha$ CETI)	42	ALNILAM ( $\epsilon$ ORIONIS)
8	MIRFAK ( $\alpha$ PERSEI)	43	ANKAA ( $\alpha$ PHOENICIS)
9	ALDEBARAN ( $\alpha$ TAURI)	44	AVIOR ( $\epsilon$ CARINAE)
10	RIGEL ( $\beta$ ORIONIS)	45	BELLATRIX ( $\gamma$ ORIONIS)
		46	BETELGEUSE ( $\alpha$ ORIONIS)
		47	CASTOR ( $\alpha$ GEMINORUM)
11	CAPELLA ( $\alpha$ AURIGAE)	48	DUBHE ( $\alpha$ URSAE MAJORIS)
12	CANOPUS ( $\alpha$ CARINAE)	49	ELNATH ( $\beta$ TAURI)
13	SIRIUS ( $\alpha$ CANIS MAJORIS)	50	ELTANIN ( $\gamma$ DRACONIS)
14	PROCYON ( $\alpha_2$ CANIS MINORIS)		
15	REGOR ( $\gamma$ VELORUM)	51	GACRUX ( $\gamma$ CRUCIS)
16	DNOCES ( $\iota$ URSAE MAJORIS)	52	HADAR ( $\beta$ CENTAURI)
17	ALPHARD ( $\alpha$ HYDRAE)	53	HAMAL ( $\alpha$ ARIETIS)
18	REGULUS ( $\alpha$ LEONIS)	54	KAUS AUSTRALIS ( $\epsilon$ SAGITTARI)
19	DENEBOLA ( $\beta$ LEONIS)	55	KOCHAB ( $\beta$ URSAE MINORIS)
20	GIENAH ( $\gamma$ CORVI)	56	MARKAB ( $\alpha$ PEGASI)
		57	MIAPLACIDUS ( $\beta$ CARINAE)
21	ACRUX ( $\alpha$ CRUCIS)	58	MIMOSA ( $\beta$ CRUCIS)
22	SPICA ( $\alpha$ VIRGINIS)	59	POLLUX ( $\beta$ GEMINORUM)
23	ALKAIK ( $\eta$ URSAE MAJORIS)	60	RIGEL KENTAURUS ( $\alpha$ CENTAURI)
24	MENKENT ( $\theta$ CENTAURI)		
25	ARCTURUS ( $\alpha$ BOOTIS)	61	SABIK ( $\eta$ OPHIUCHI)
26	ALPHECCA ( $\alpha$ CORONAE BOREALIS)	62	SCHEDAR ( $\alpha$ CASSIOPEIAE)
27	ANTARES ( $\alpha$ SCORPII)	63	SHAULA ( $\lambda$ SCORPII)
28	ATRIA ( $\alpha$ TRIANGULI)	64	SUHAIR ( $\lambda$ VELORUM)
29	RASALHAGUE ( $\alpha$ OPHIUCHI)	65	ZUBENELGENUBI ( $\alpha$ LIBRAE)
30	VEGA ( $\alpha$ LYRAE)		
31	NUNKI ( $\sigma$ SAGITTARI)		
32	ALTAIR ( $\alpha$ AQUILAE)		
33	DABIH ( $\beta$ CAPRICORNI)		
34	PEACOCK ( $\alpha$ PAVONIS)		
35	DENEBO ( $\alpha$ CYGNI)		
36	ENIF ( $\epsilon$ PEGASI)		
37	FOMALHAUT ( $\alpha$ PISCIS ASTR.)		

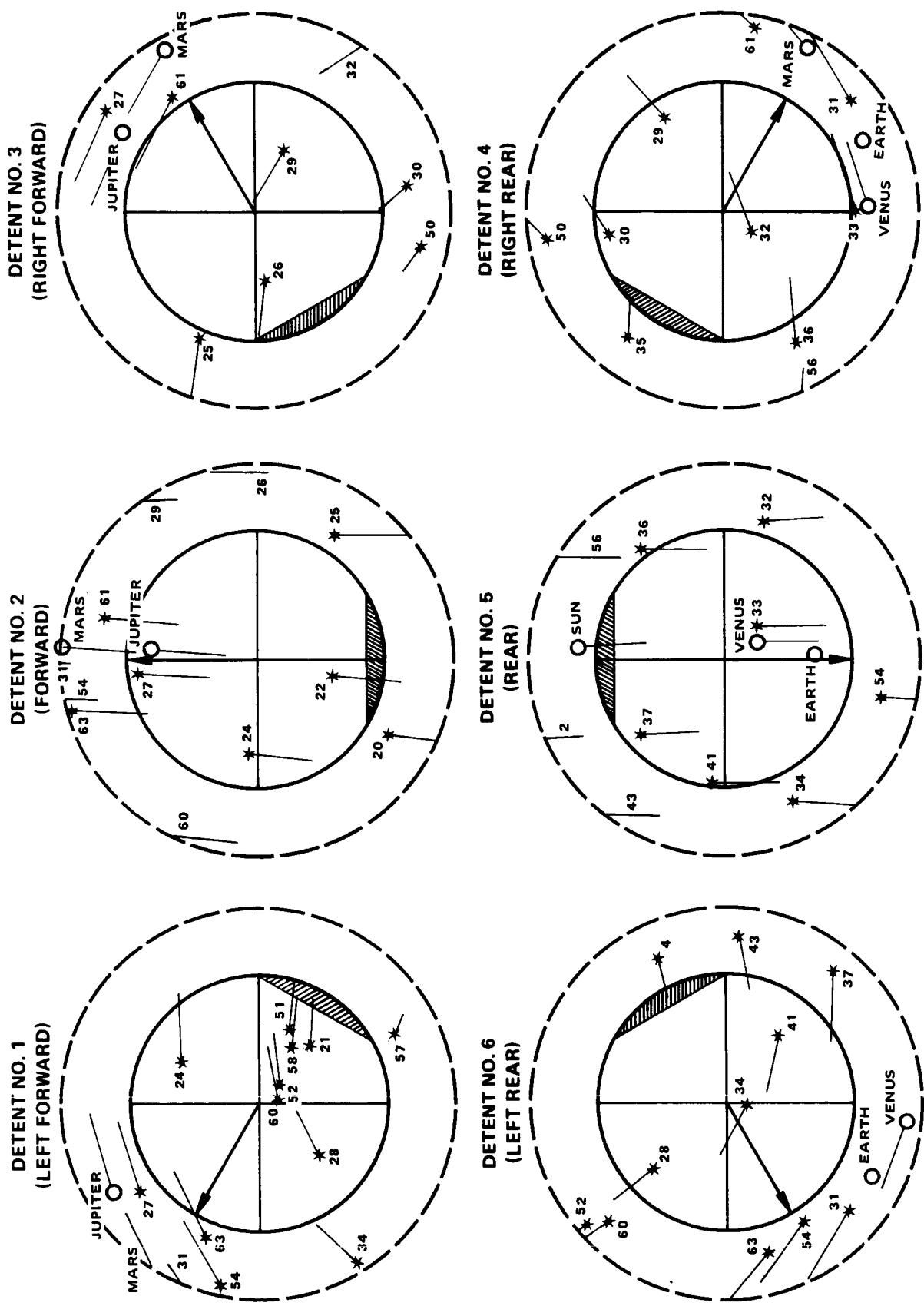
TABLE 1 STARS CONSIDERED



SITE: FRA MAURO ( $3.67^{\circ}$ S,  $17.46^{\circ}$ W)  
LANDING AZIMUTH:  $-76.3^{\circ}$

DATE: FEB 5, 1971  
APPROX. VIEWING TIME: 10:00 (GMT)

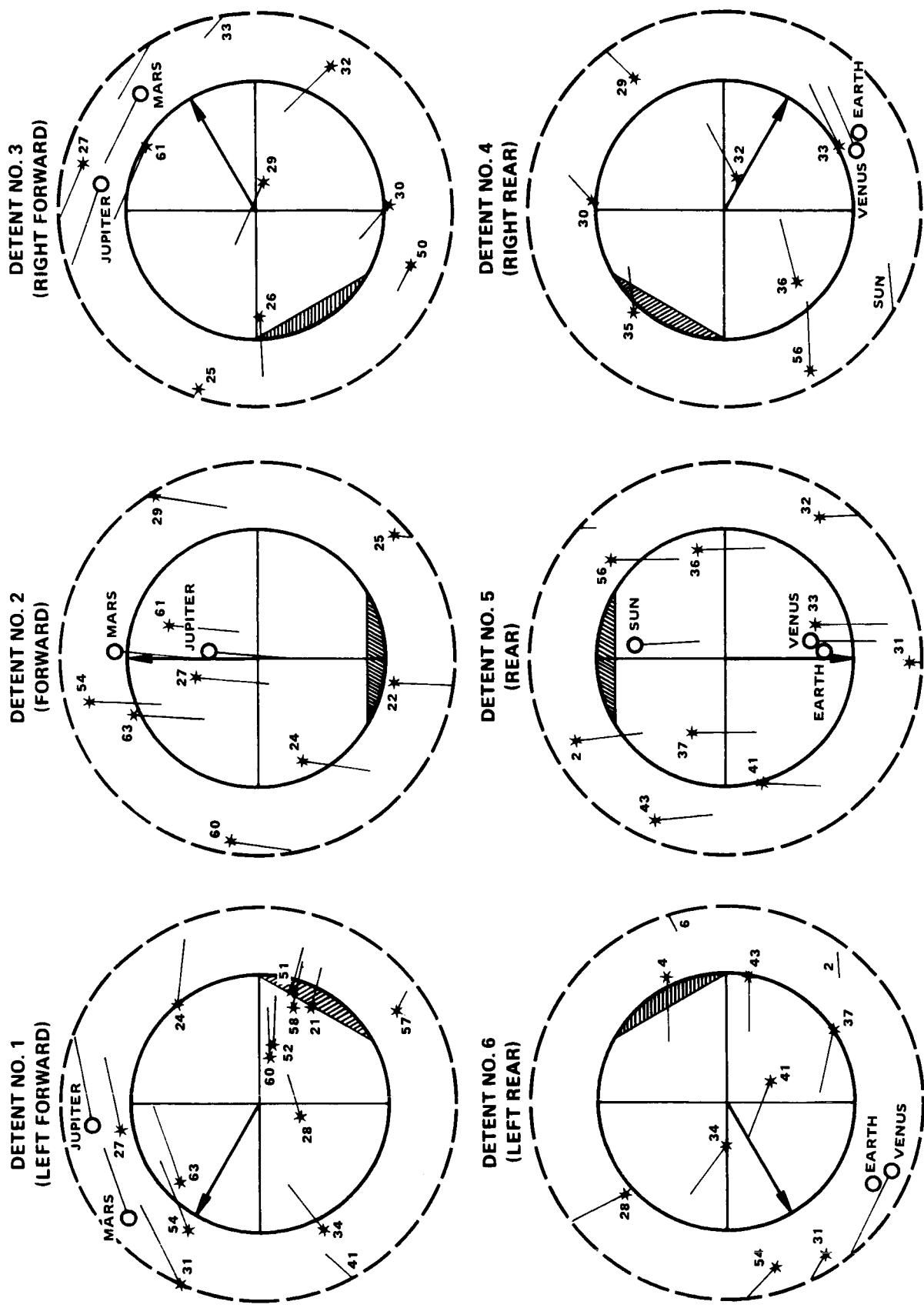
FIGURE 1 - STARS AND PLANETS APPEARING IN LM DETENTS DURING LUNAR STAY



SITE: FRA MAURO ( $3.67^{\circ}$ S,  $17.46^{\circ}$ W)  
LANDING AZIMUTH:  $-87.4^{\circ}$

DATE: MAR 7, 1971  
APPROX. VIEWING TIME: 01:00 (GMT)

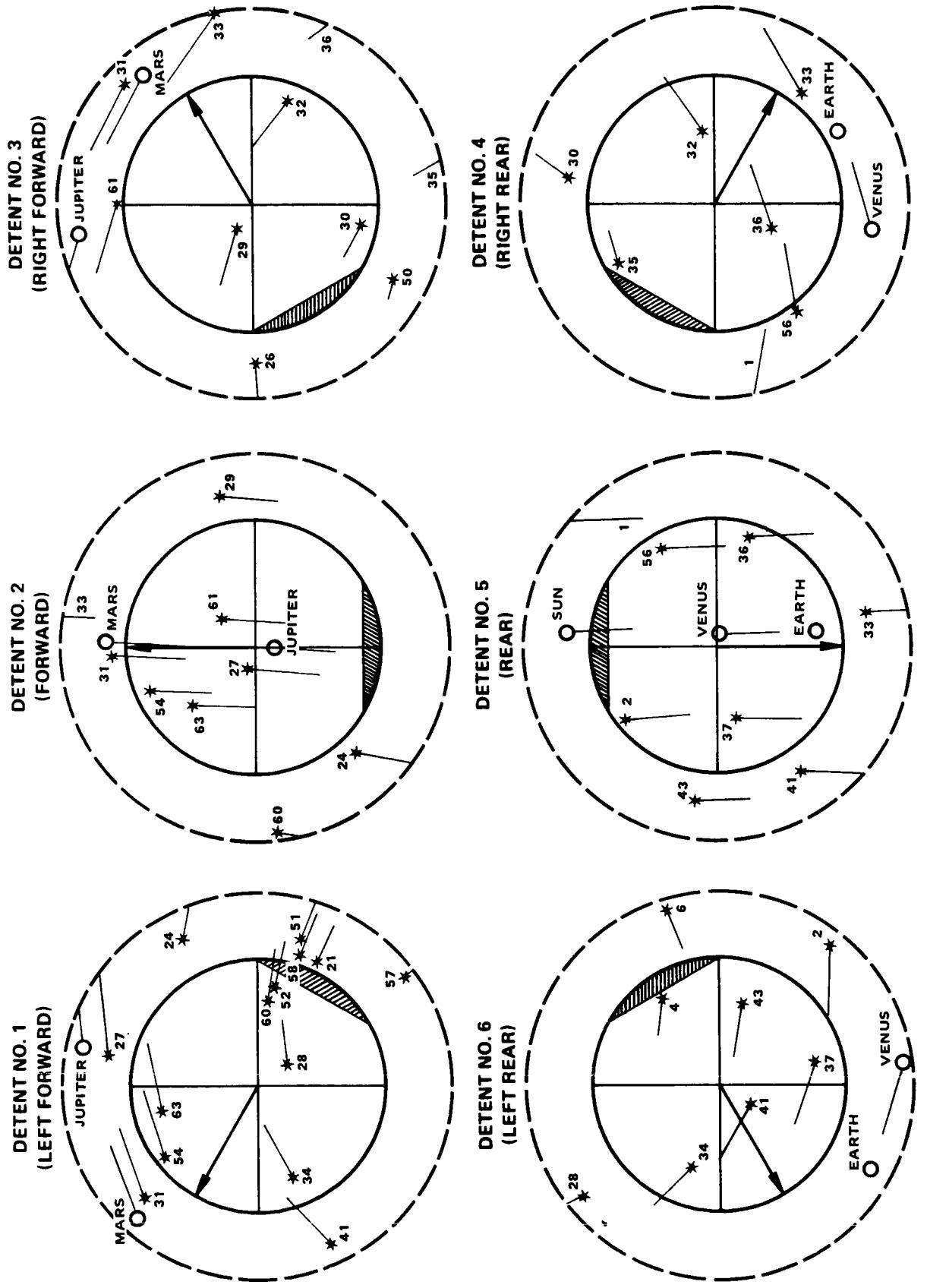
FIGURE 2 - STARS AND PLANETS APPEARING IN LM DETENTS DURING LUNAR STAY



SITE: FRA MAURO ( $3.67^{\circ}$ S,  $17.46^{\circ}$ W)  
LANDING AZIMUTH:  $-87.4^{\circ}$

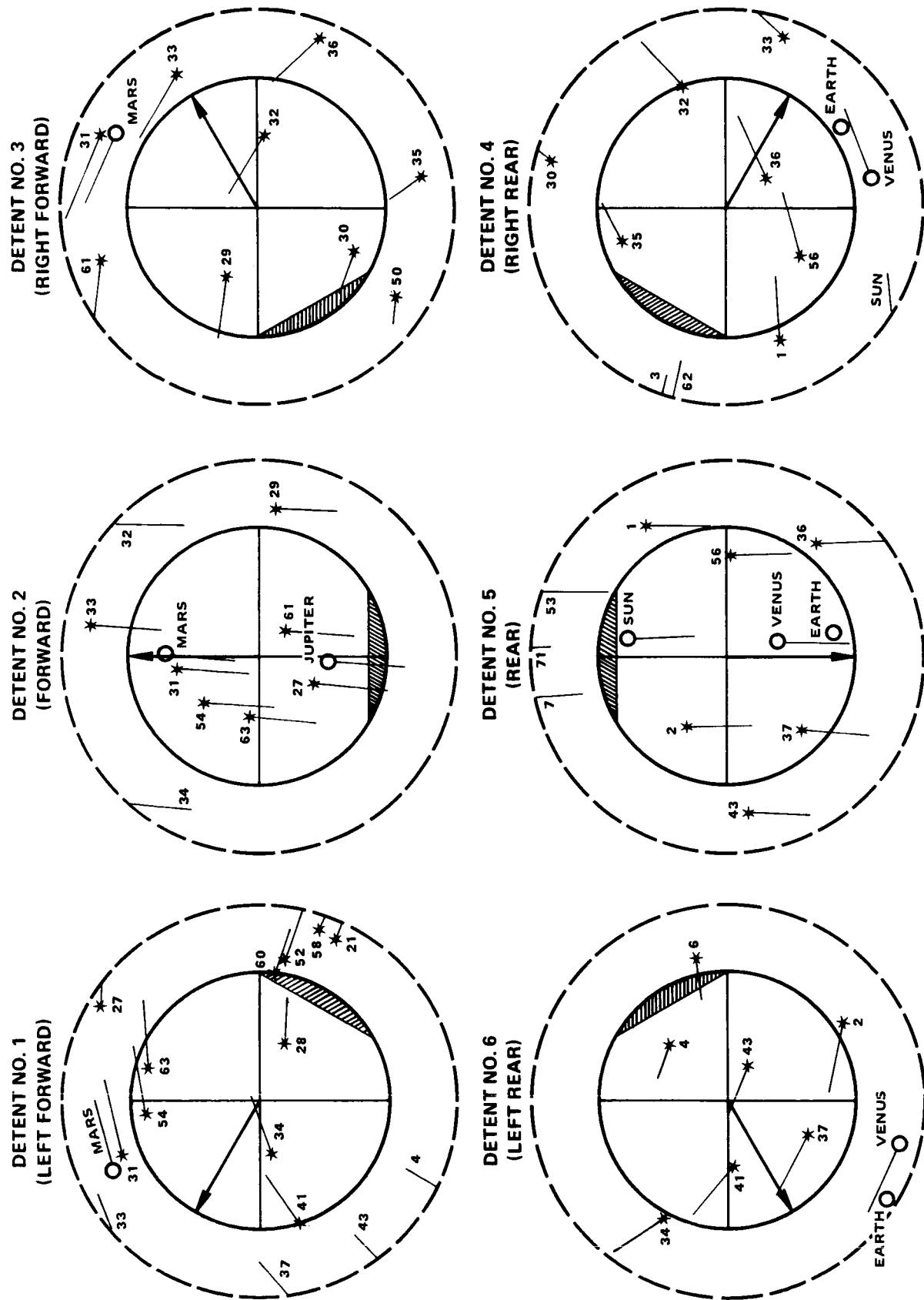
DATE: MAR 8, 1971  
APPROX. VIEWING TIME: 01:00 (GMT)

FIGURE 3 - STARS AND PLANETS APPEARING IN LM DETENTS DURING LUNAR STAY



DATE: APRIL 5, 1971  
APPROX. VIEWING TIME: 09:00 (GMT)  
SITE: FRA MAURO ( $3.67^{\circ}$ S,  $17.46^{\circ}$ W)  
LANDING AZIMUTH:  $-87.4^{\circ}$

FIGURE 4 - STARS AND PLANETS APPEARING IN LM DETENTS DURING LUNAR STAY



SITE: FRA MAURO ( $3.67^{\circ}$ S,  $17.46^{\circ}$ W)  
LANDING AZIMUTH:  $-87.4^{\circ}$

DATE: APRIL 6, 1971  
APPROX. VIEWING TIME: 13:00 (GMT)

FIGURE 5 - STARS AND PLANETS APPEARING IN LM DETENTS DURING LUNAR STAY